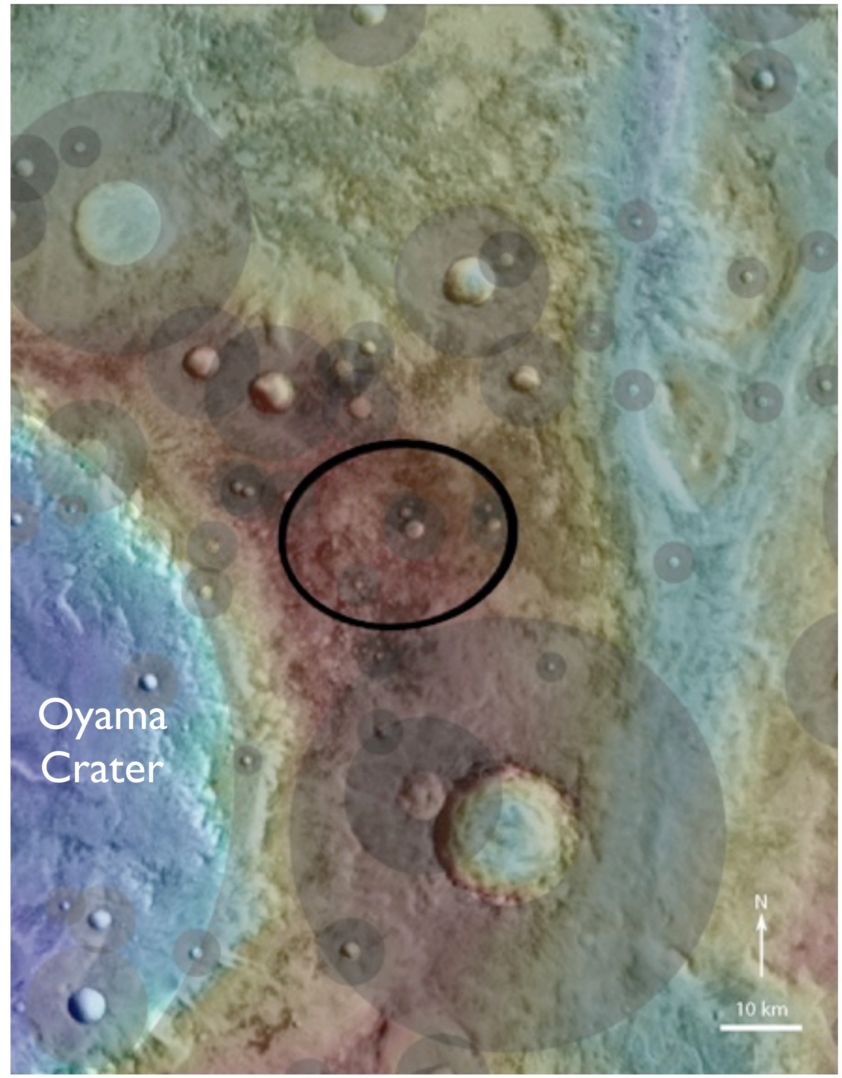
Deformation of Mawrth Landing Ellipse Bedrock Due to the Oyama Impact

Dawn Y. Sumner, Geology, UCDavis

- I: Impact Predictions
  - Age of the Mawrth Area Bedrock
  - Cratering Rates at 4.0-3.8 Ga
- II : Predicted Deformation From the Oyama Impact
  - Senft & Stewart (2009) Models for Deformation
- III : Ejecta & Brecciation
  - Present in Patches
  - Consistent with Predictions
- VI : Implications for a MSL Mission

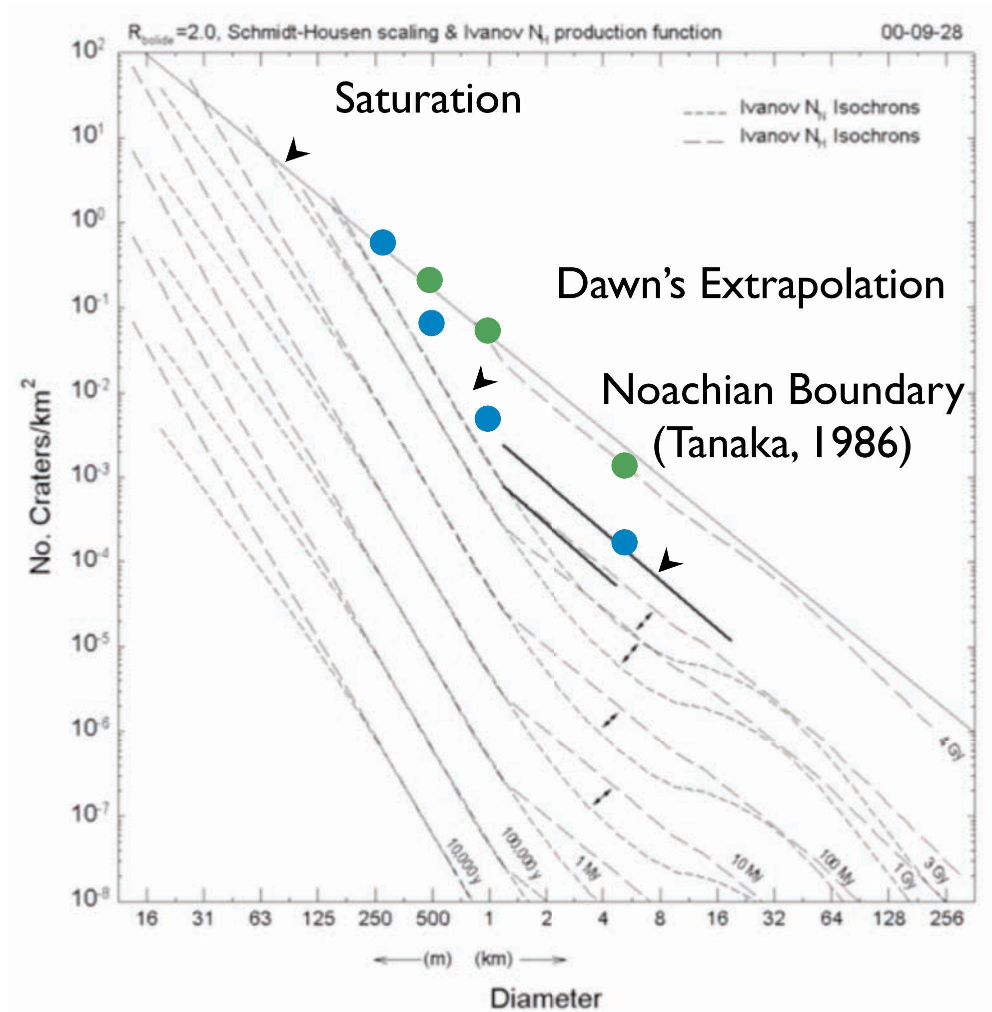


Age of Mawrth Bedrock & Cratering Rates

- Rocks are Broken by Stress, not Age, except that a greater age provides more opportunities for disruption and >3.5 Gy there were many more impacts.

- Age of Mawrth Bedrock
  - Crater Counts: Early to Late Noachian
    Michalski and Noe Dobrea, 2007, Geology
  - Mineralogy Model: Phyllosian, e.g. Early to Mid-Noachian
    Bibring et al., 2006, Science

- Craters per 300 km^2 (~ellipse size)
  - 300 d≥250 m Craters at Saturation
  - 12 - 50 d≥500 m Craters 3.8 Gy - Saturation
  - 1 - 12 d≥1 km Craters 3.8 - 4.0 Gy
  - 0.1 - 1 d≥4 km Craters 3.8 - 4.0 Gy



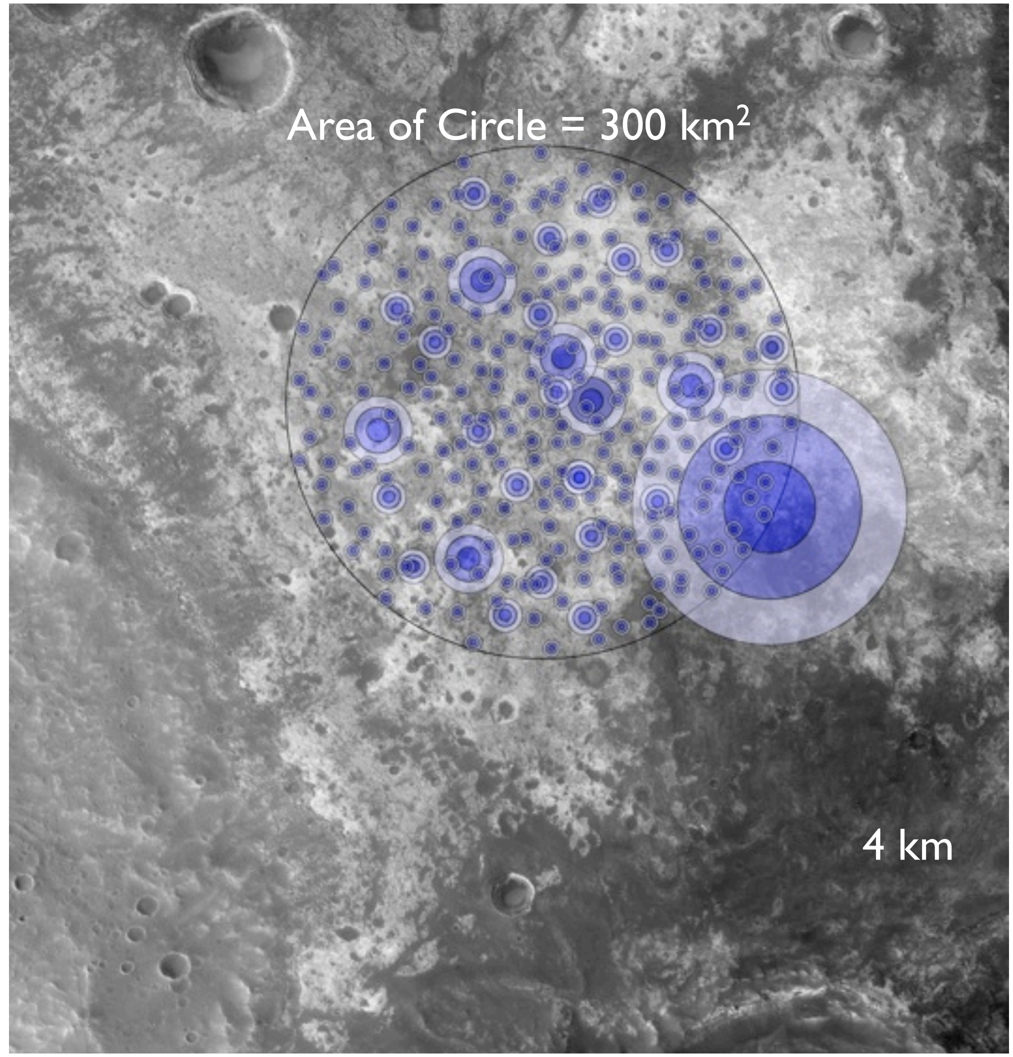
Hartmann & Neukum 2001

Predicted Crater Distributions

- Craters
  1x 4 km Diameter
  6x 1 km Diameter
  24x 500 m Diameter
  269x 250 m Diameter

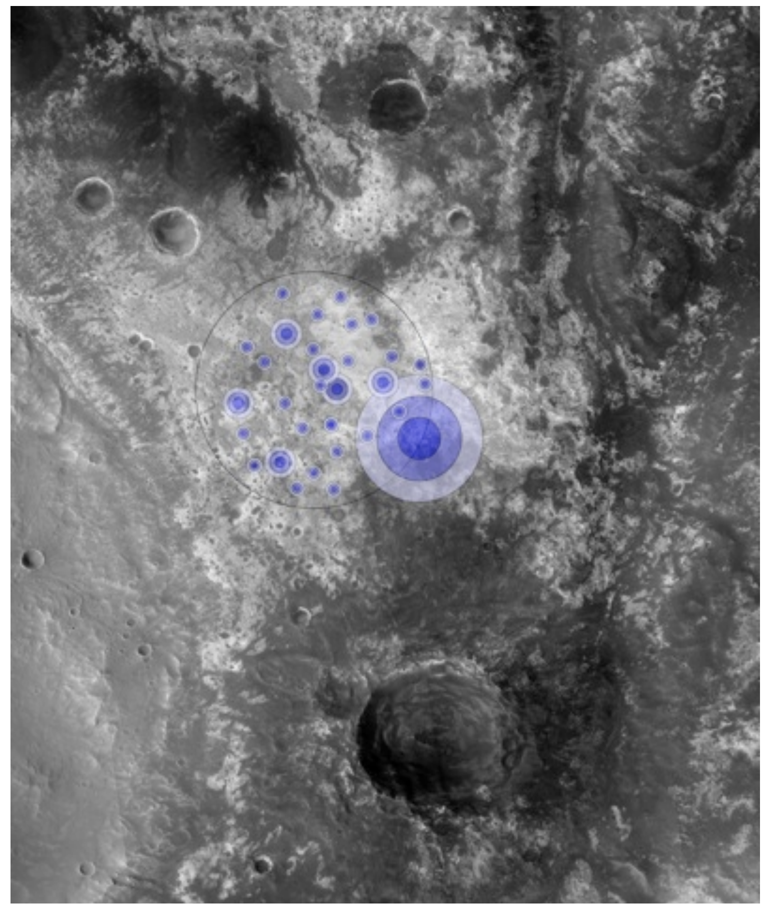
- Color Scheme
  Dark Blue = Crater
  Medium Blue = +1 Radius
  Light Blue = +1 Diameter

  (damage extensive in 1 radius,
  present in 1 diameter)



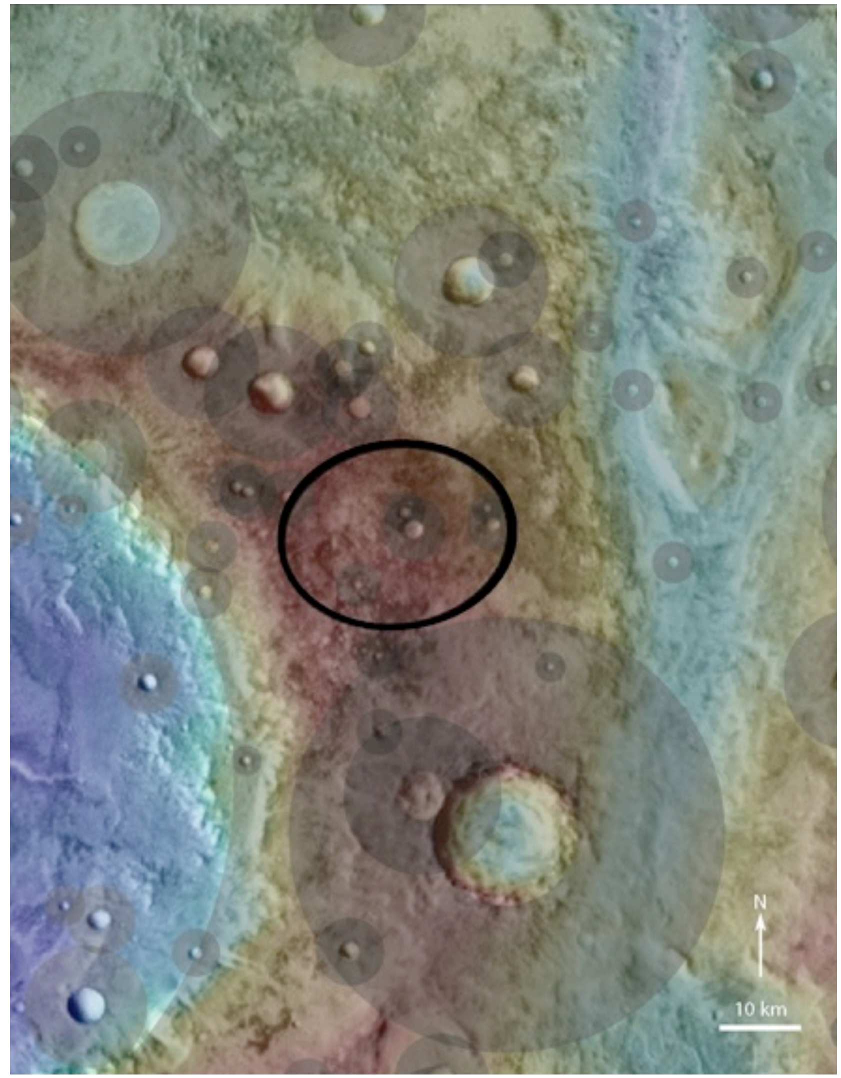
Observed vs Predicted Crater Distribution

Need significant deflation to remove effects even if crater not observed since have brecciation to at least 1 radius depth

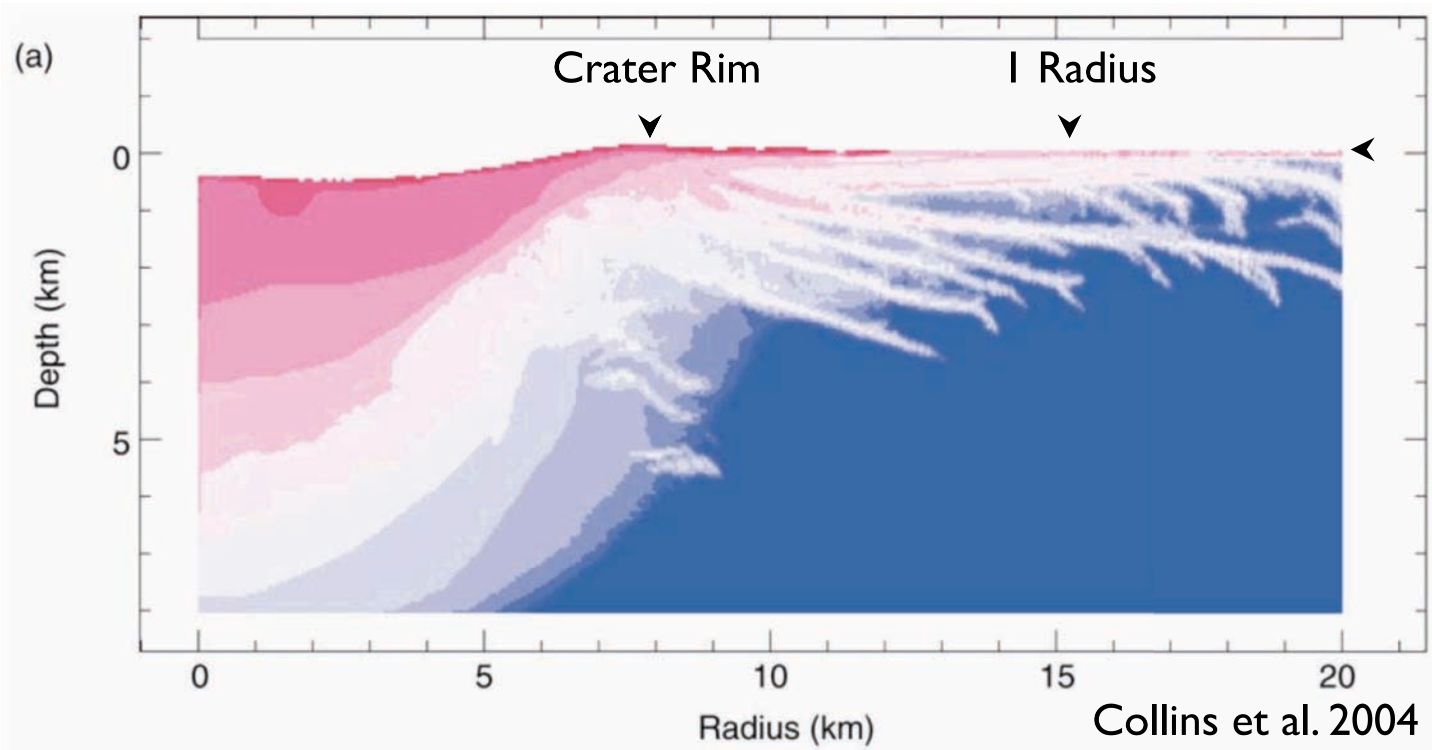


Damage Predicted in the Mawrth Ellipse

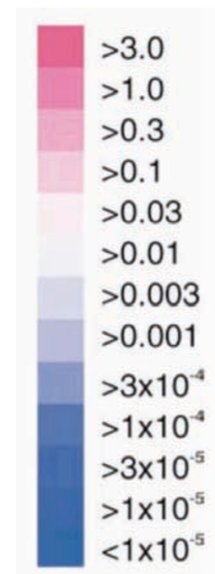
- Grey Circles: 2 radii beyond crater rim
- Real Problem: Proximity to Oyama Crater
- Oyama Crater
  - Younger Than Landing Ellipse Bedrock
  - ~100 km in Diameter
  - Ellipse Edge: ~8 km From Rim



Deformation from 1-2 Radii Beyond Crater Rim



Deformation at Free Surface



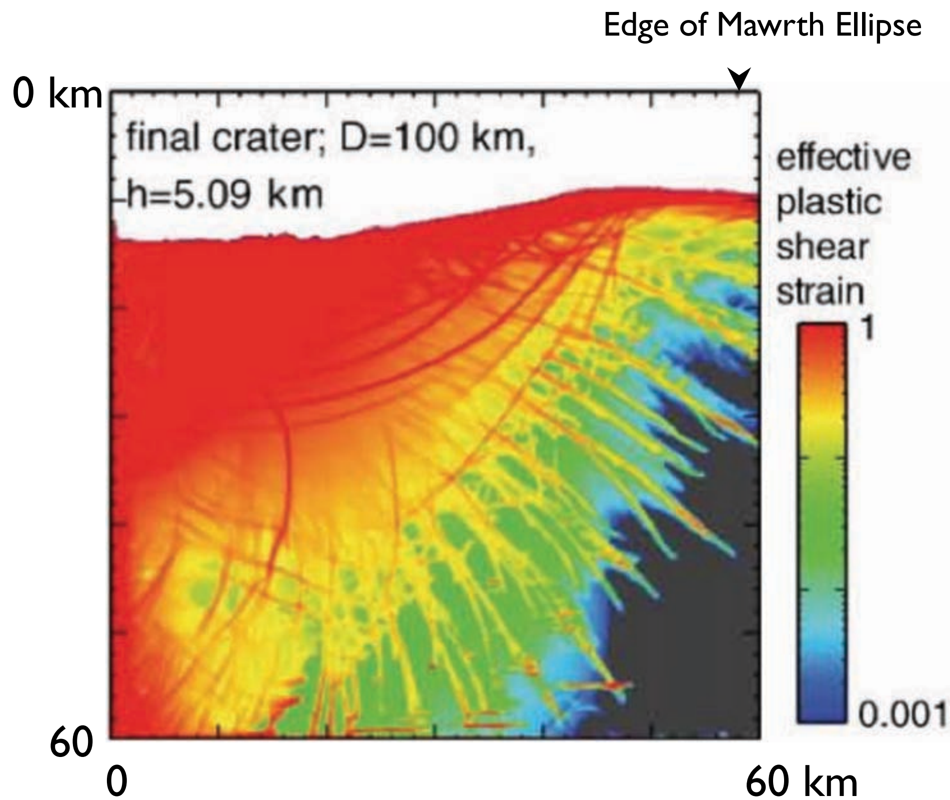
Total Plastic Shear Strain

The pattern of deformation in this image is ubiquitous air gun experiments, computational models, and natural craters. The formation of "feathery" fractures near the surface for substantial distances is a fundamental response of rock-like rheologies to the shock and surface waves produced by impact.

Mawrth & Oyama Crater

- Cratering model of 100 km diameter craters
  - Simulations of Impact Strain Predict Extensive Bedrock Damage (Senft & Stewart 2009, EPSL)
  - Models appropriate for a similar crater size on any rocky planet

"In general the gross level of structural deformation will be similar around any similar size crater on any rocky planet. The scaling to different gravities was done in the impact conditions that made that size crater. A primary difference between Earth and Mars is the different mean impact velocities -- ~20 km/s for asteroids hitting Earth; ~5 km/s for asteroids hitting Mars. As a result, there is less impact (silicate) melt generated on Mars for the same size crater. However, the shock pressures (and hence the deformation) in the rock around the crater rim is similar in both cases." - Sarah Stewart, pers. comm. 11 May 2011

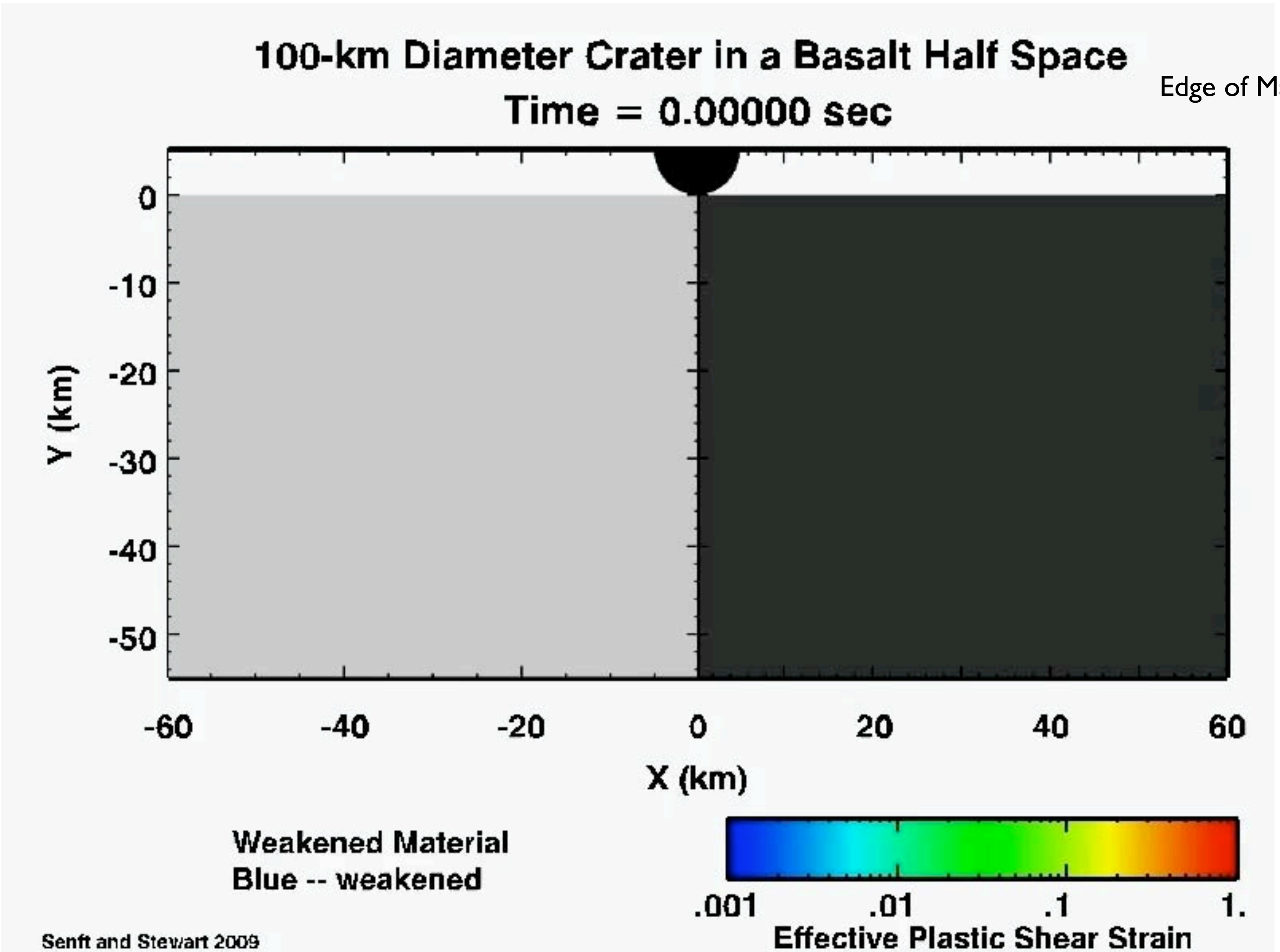


Brecciated to >1 km depth at ellipse distance

(Shear strain of 1.0 = a square sheared to a parallelogram with a corner angle of 45°.)

Movie of Deformation - 100 km Final Crater

Note: movie does not show the final crater morphology; crater collapse continues for 100's sec

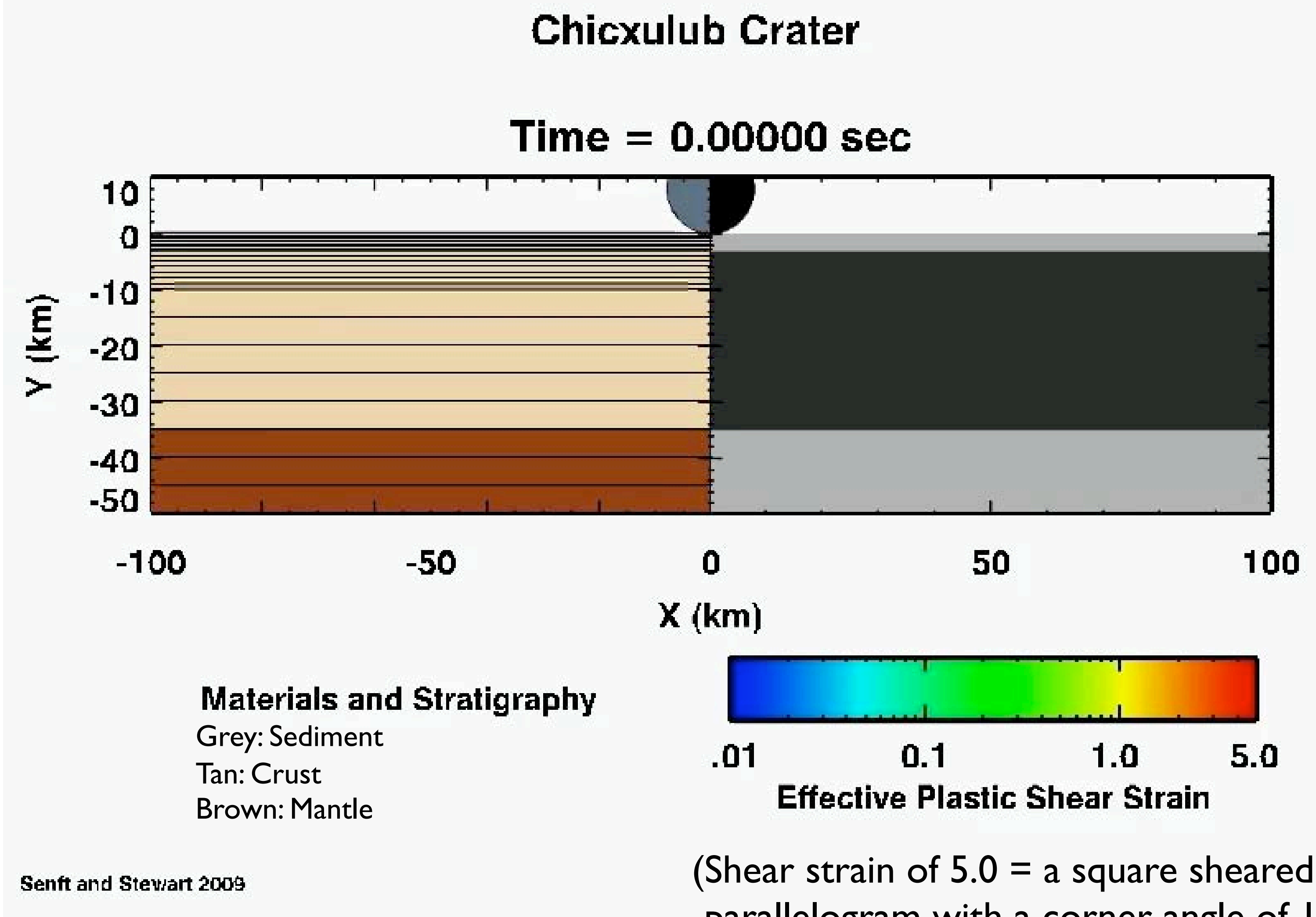


Edge of Mawrth Ellipse

Movie of Deformation – ~150 km Crater

Modeled Crater: Peak Ring at r=40 km, Outer Ring at r~70 km

Shear Strain of 5 to 1 km depth beyond Outer Ring



Grey: Sediment

Tan: Crust

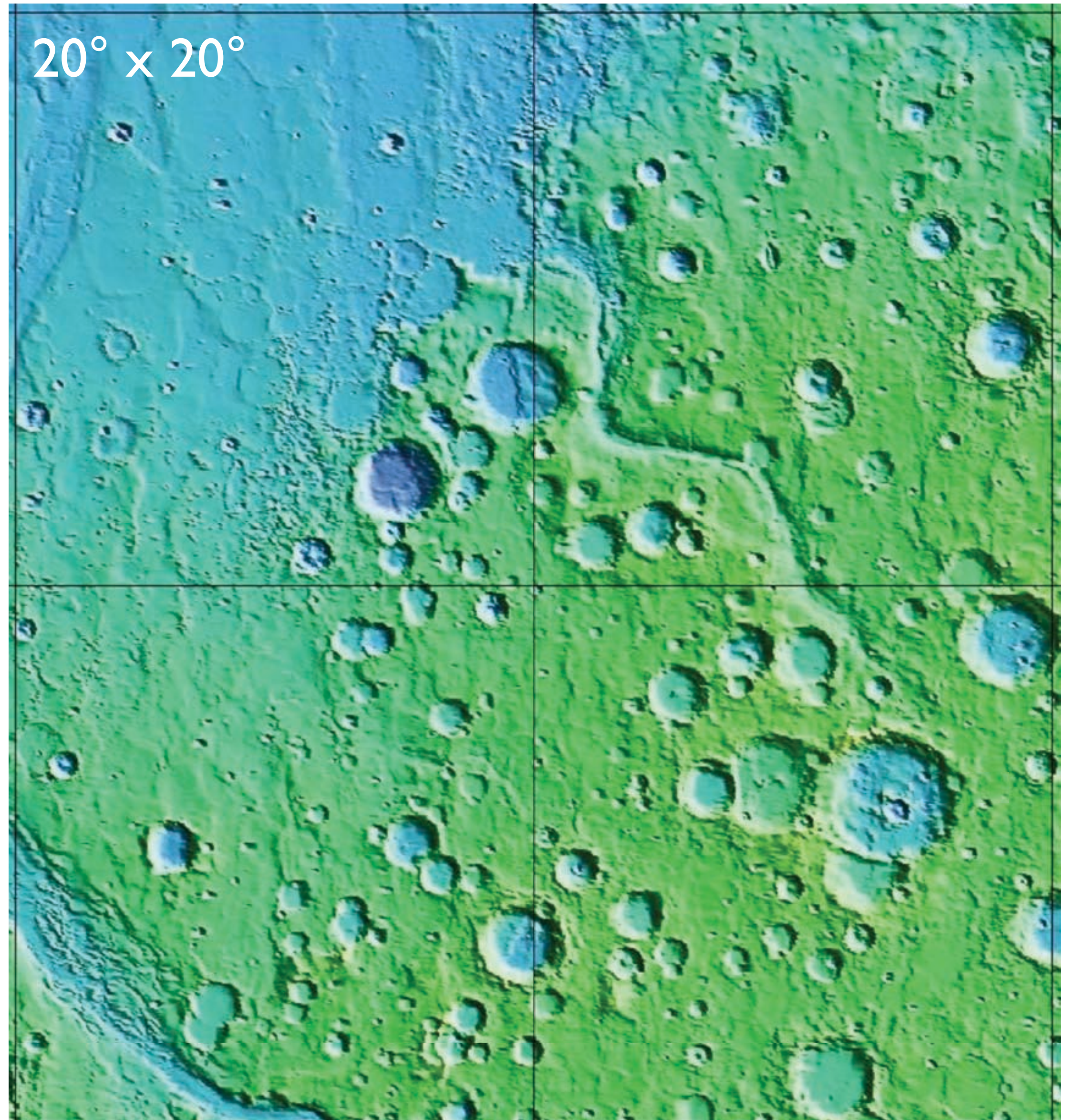
Brown: Mantle

(Shear strain of 5.0 = a square sheared to a parallelogram with a corner angle of 11°.)

Implications For the Mawrth Ellipse

Extensive Brecciation Expected

(and observed - see Sumner's Mawrth presentation for the Sept. 2010 Landing Site Workshop)



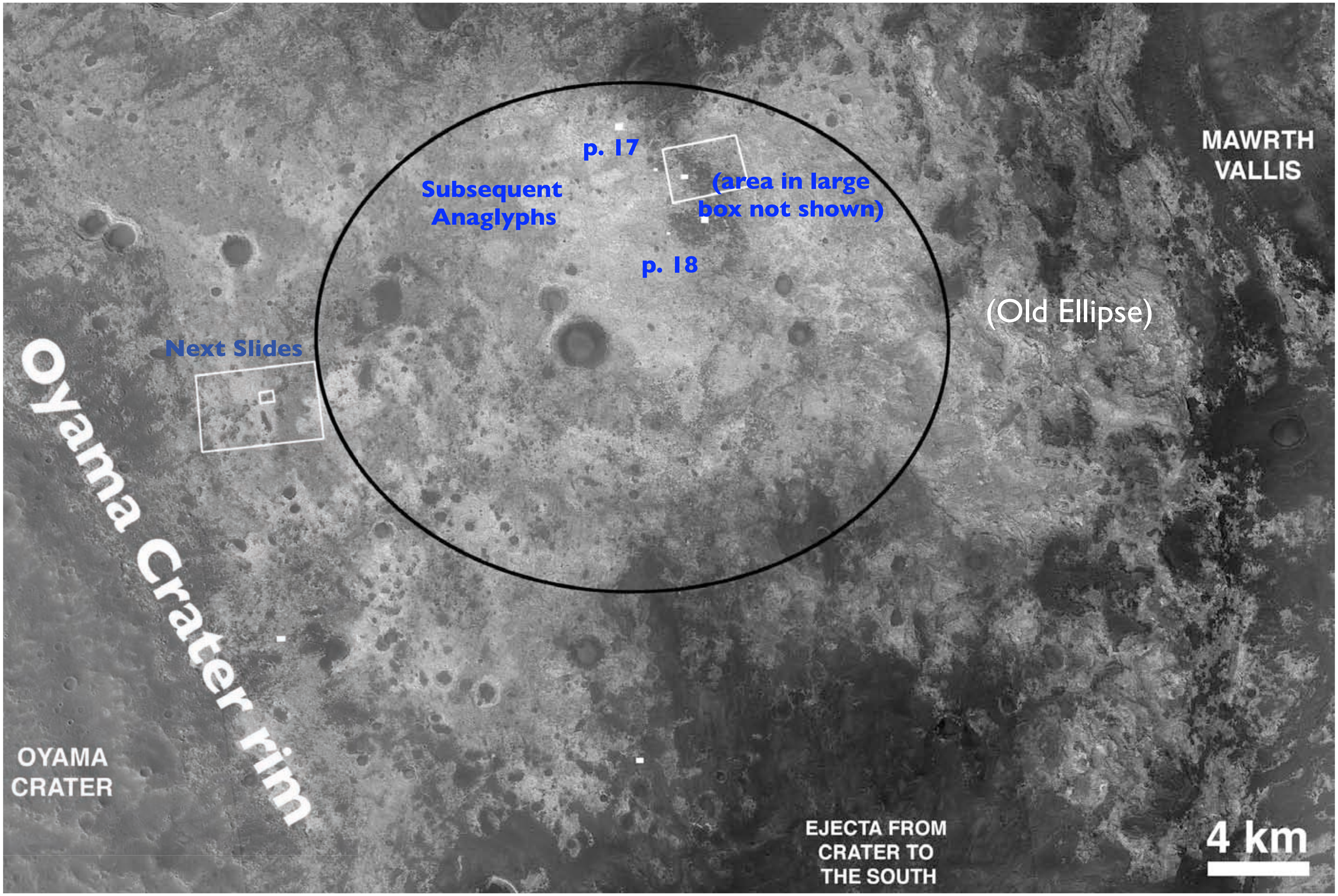
The following slides document secondary craters and ejecta near and in the Mawrth ellipse, demonstrating:

1. The bedrock is older than Oyama Crater.

2. The >1 km of highly fractured rock has not been eroded away.

Please see Sumner, 2010, Workshop #4 Presentation for Documentation of Brecciation of the bedrock in the Mawrth Landing Ellipse
Physical Outcrop Characteristics of the Mawrth Candidate Landing Site & the Potential Role of Impacts in Shaping Stratigraphy
http://marsoweb.nas.nasa.gov/landingsites/msl/workshops/4th_workshop/program.html

The Continuous or Primary Ejecta Facies from Oyama Crater should, at one time, have covered the area shown here. Remnants remain. Page numbers and white boxes indicate the location of pictures shown on subsequent pages/slides.

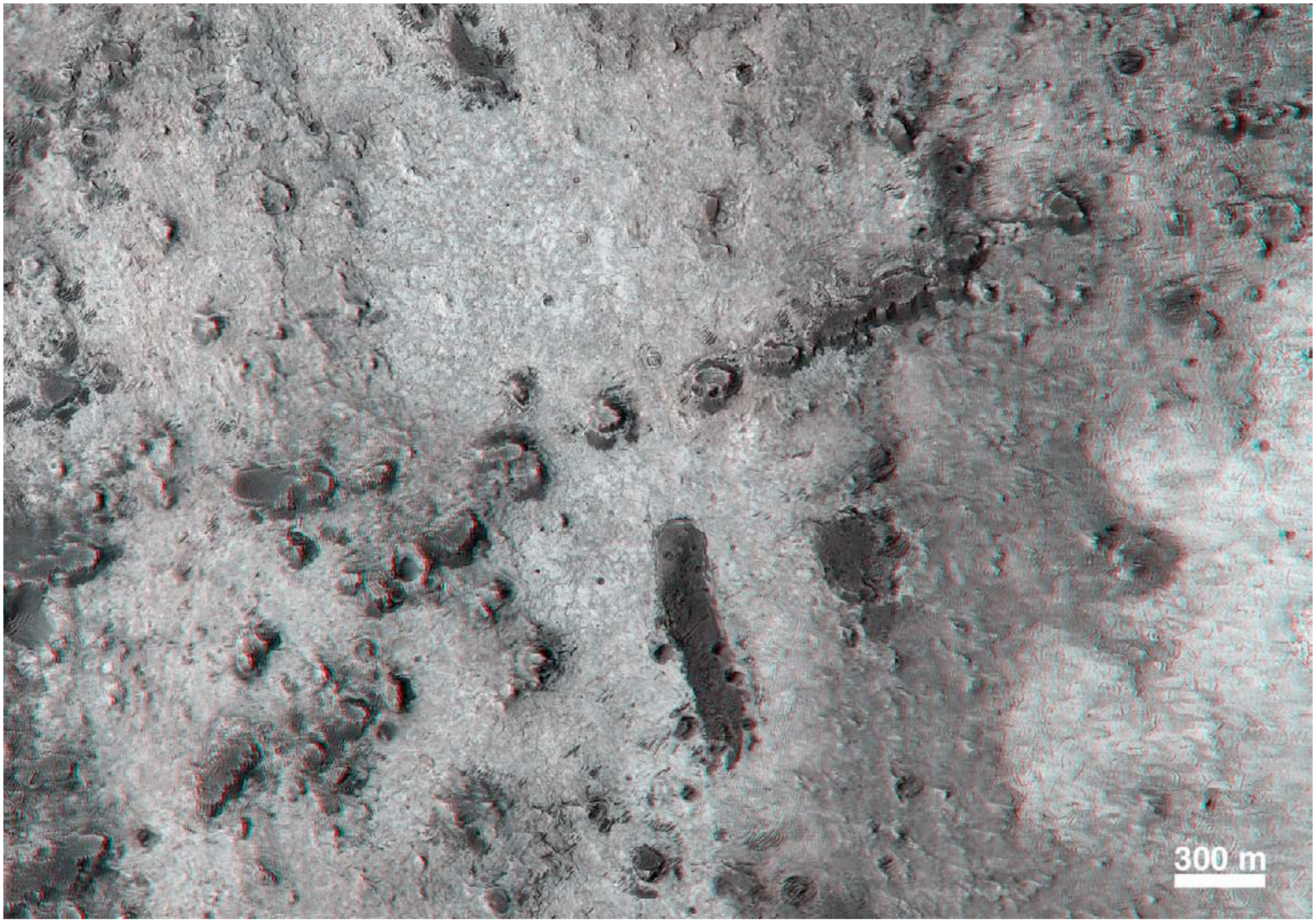


(Images & interpretations courtesy of Ken Edgett)

mosaic of CTX images

Chain of dark buttes interpreted as the remains of Oyama secondary craters (differential erosion has put them up on "pedestals"). See next slide for a zoomed-in view of two of these…

3-D



(Images & interpretations courtesy of Ken Edgett)

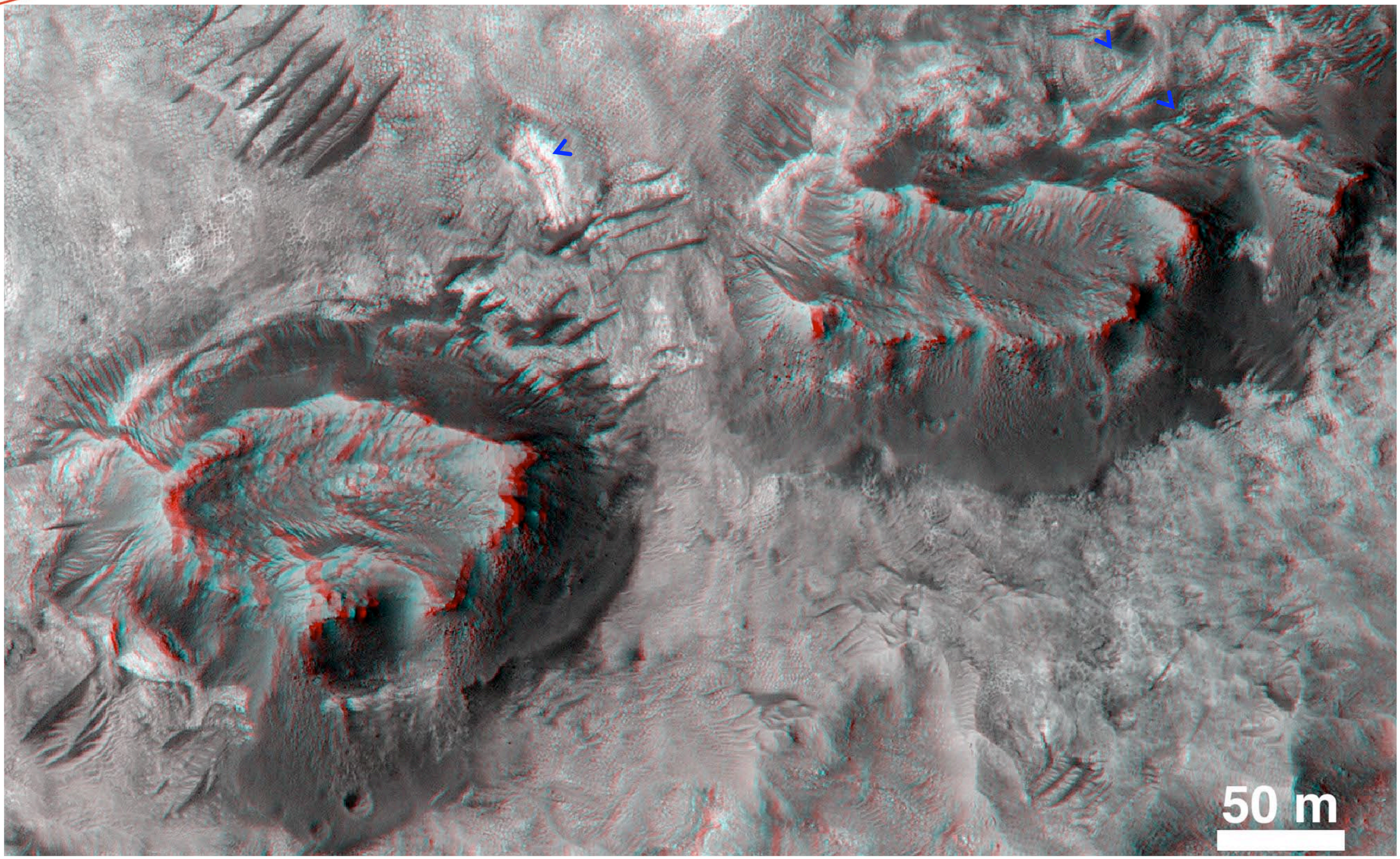
HiRISE PSP_010882_2040 & PSP_010816_2040

Close-up of the remains of two (proposed) Oyama secondary craters.

These secondaries would likely have been above some of the crater's continuous ejecta deposit, but might themselves have also been buried within it.

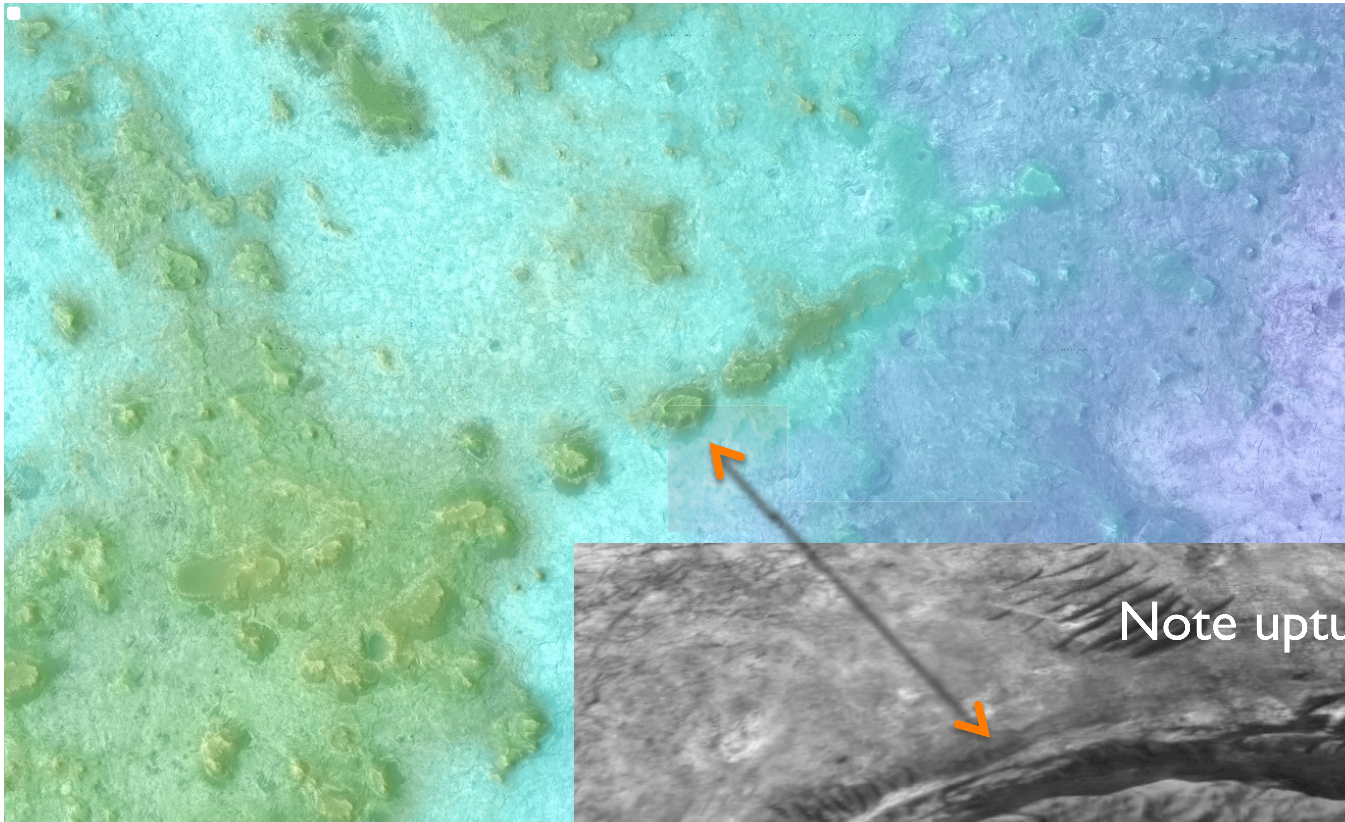
Ejecta Clasts?

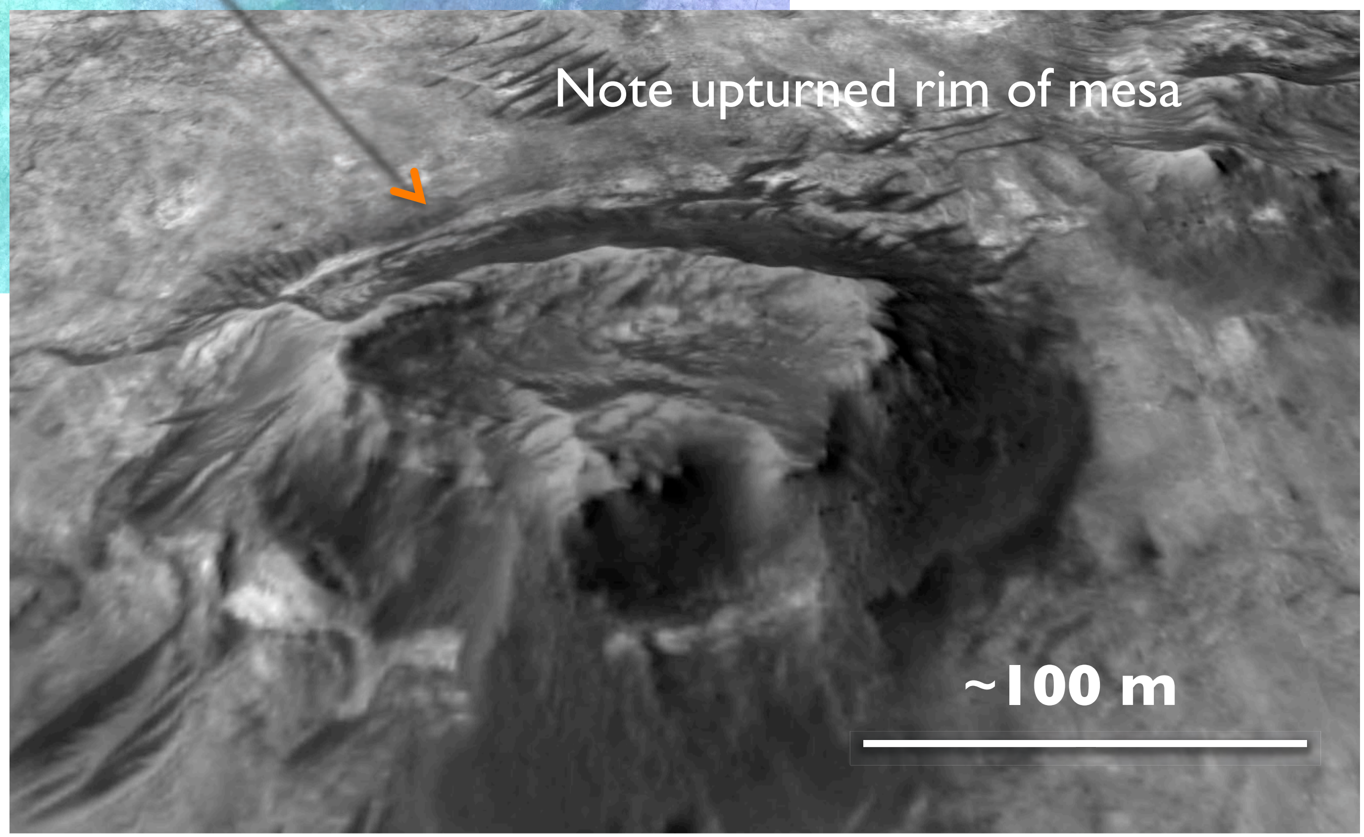
3-D



(Images & interpretations courtesy of Ken Edgett)

HiRISE PSP_010882_2040 & PSP_010816_2040

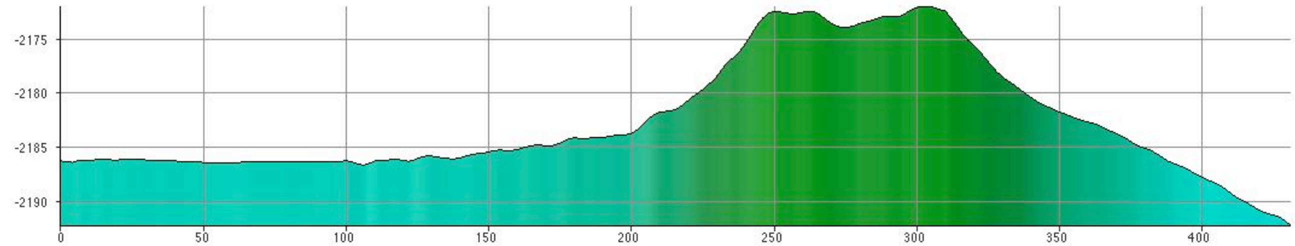




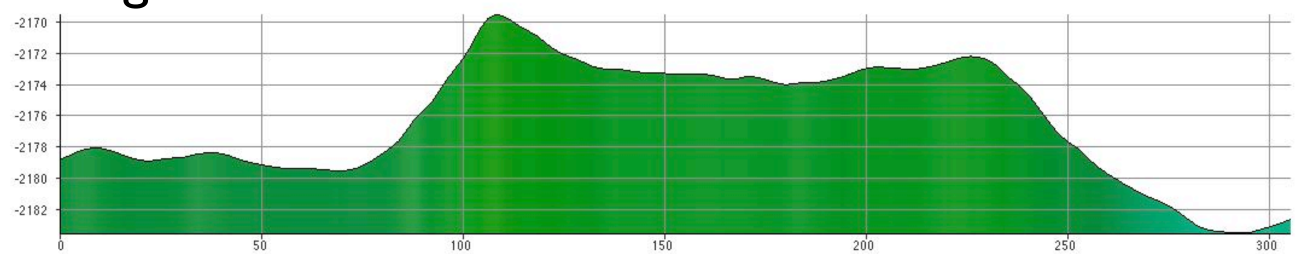
(Images & interpretations courtesy of Sanjeev Gupta)

Topographic Profile Across Mesa on Previous Page

Across axis



Along axis



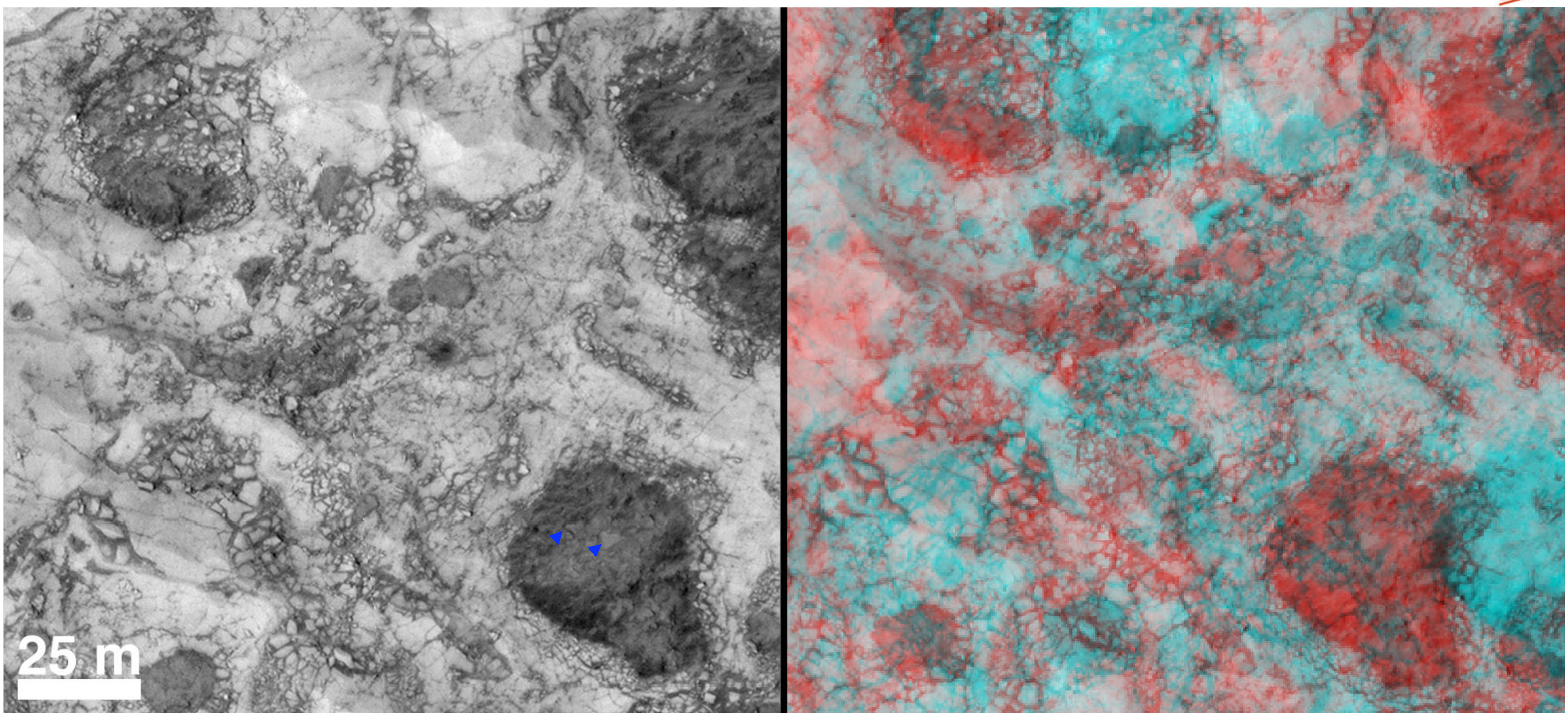
(Noe-Dobrea et al 4th MSL Workshop 2010)

(Images & interpretations courtesy of Sanjeev Gupta)

Possible Remnants of the Oyama Continuous "Ejecta" Facies from the candidate MSL landing ellipse

Much of Oyama's continuous ejecta facies—which would include both material ejected from the crater and material ripped up from the surrounding terrain—has been eroded away. However, patches of ejecta are still present. These dark, rugged hills are tentatively interpreted as ejecta remnants.

3-D

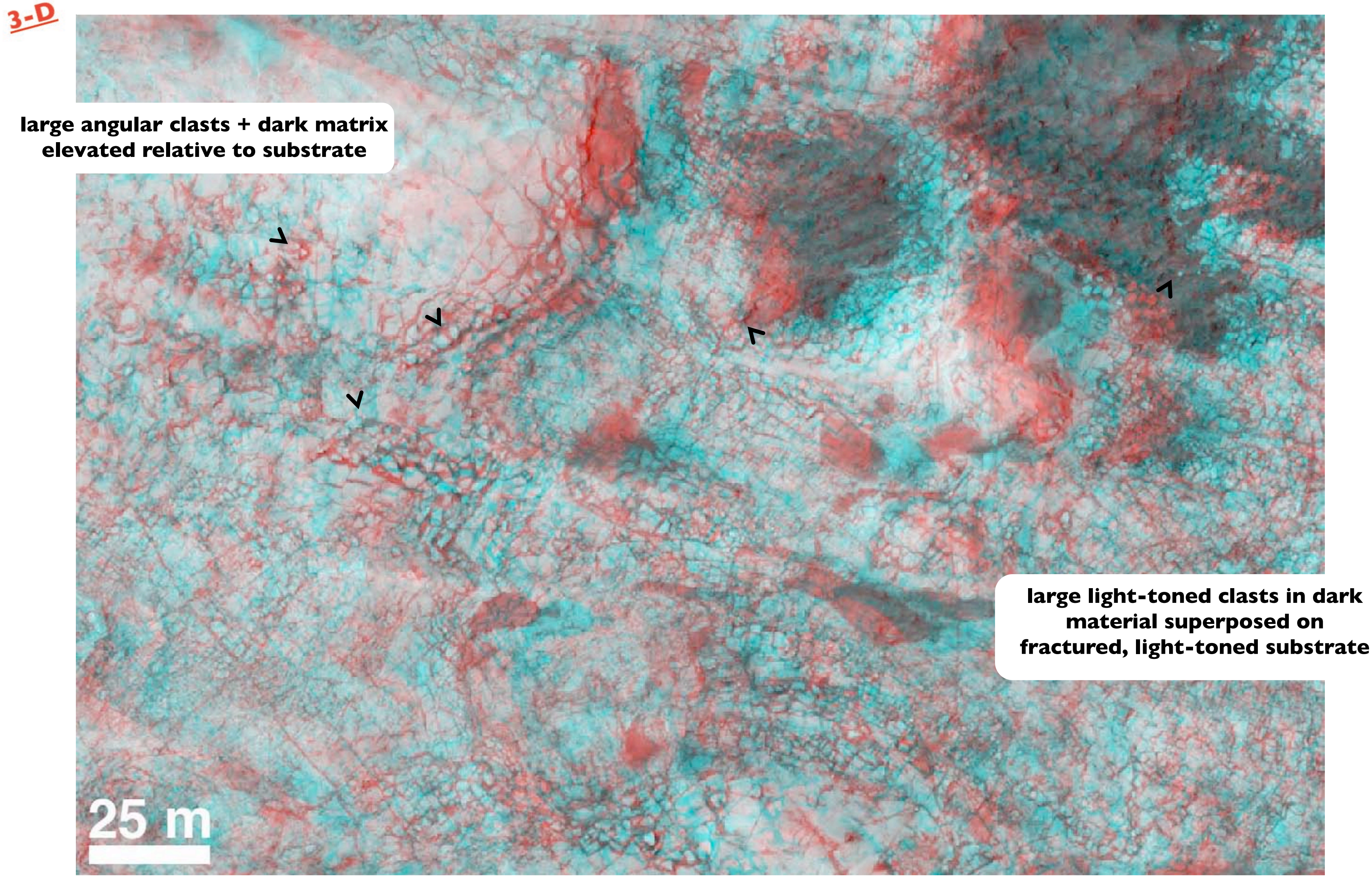


Large, angular clasts in mound of dark, rough material

PSP_006676_2045 & PSP_007612_2045

(Images & interpretations courtesy of Ken Edgett)

Ejecta Remnants and Damage (brecciation) to the substrate



(Images & interpretations courtesy of Ken Edgett)

HiRISE PSP_006676_2045 & PSP_007612_2045

Layering vs. Breccia

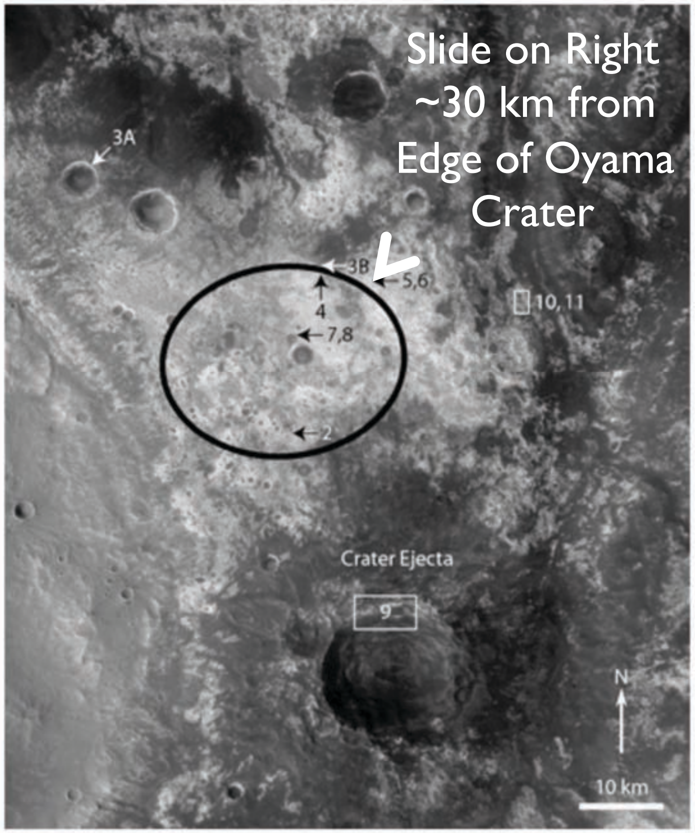
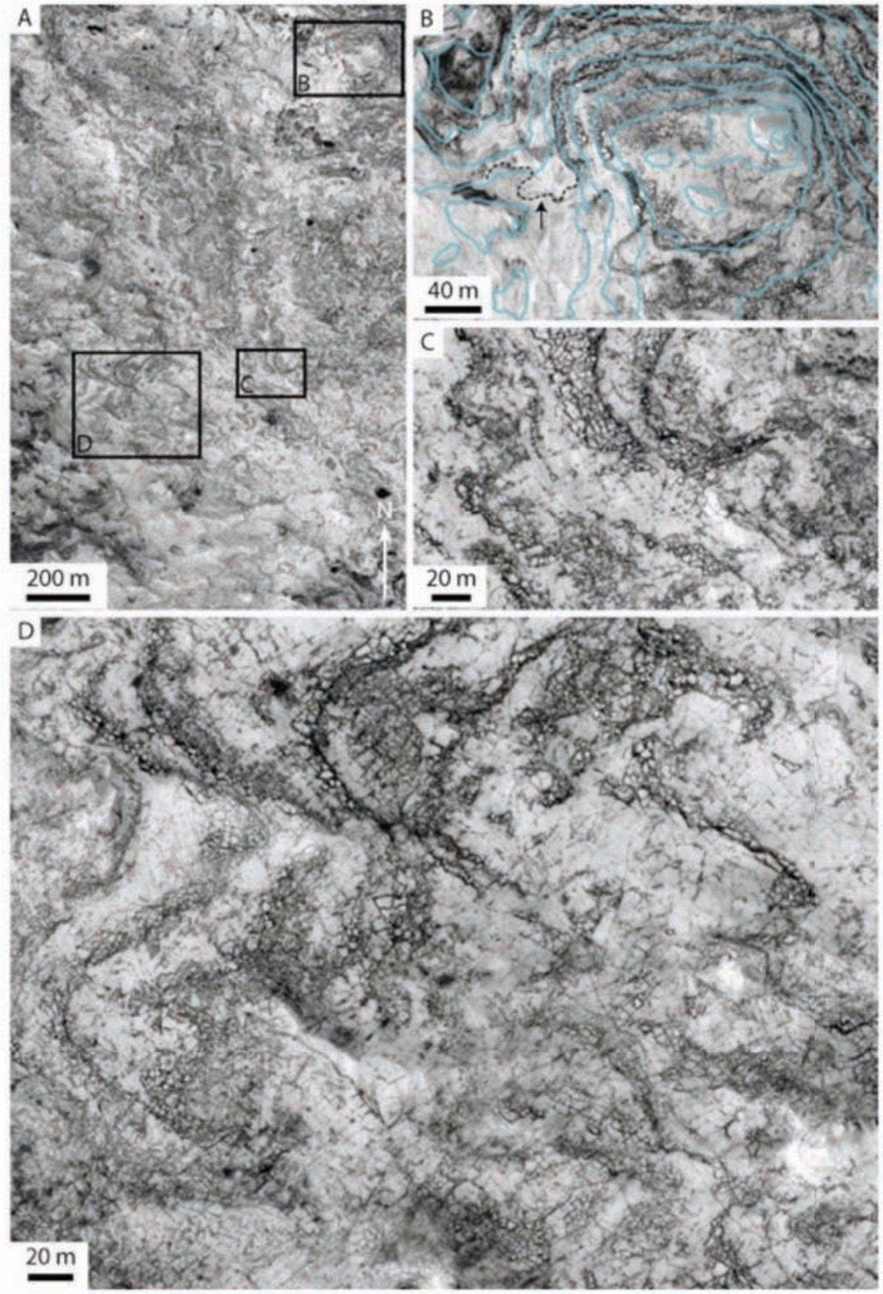


Figure on Right Located at 5 in Above Image

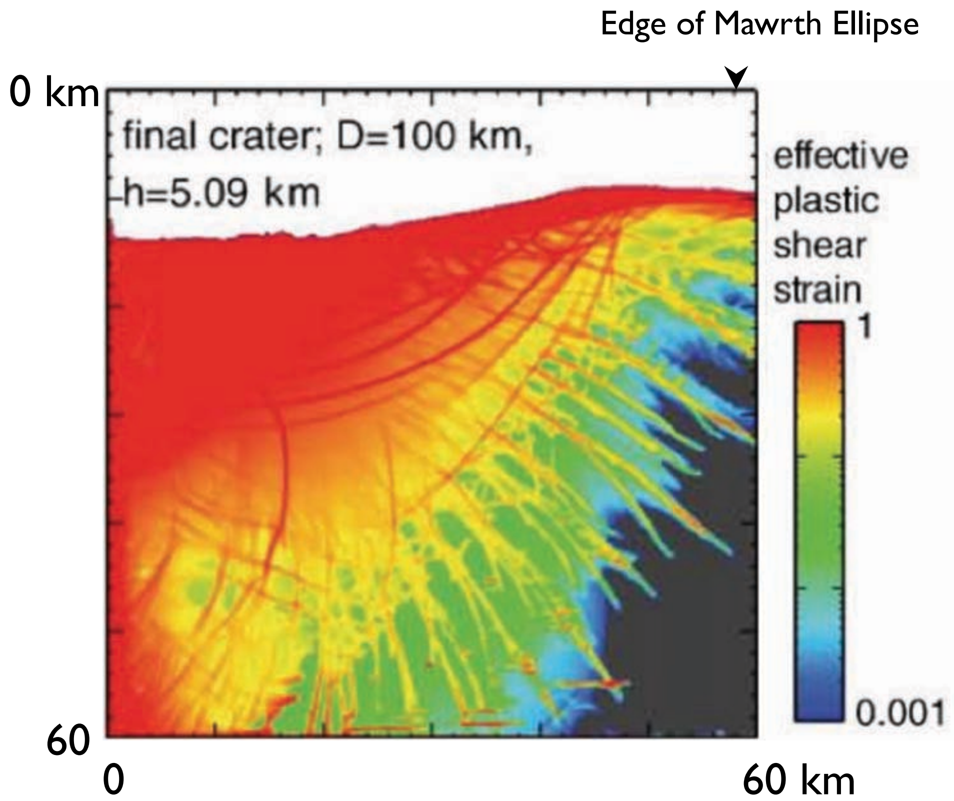
Right: Arcuate breccia pods defining apparent layering from HiRISE image PSP_006676_2045. A) Context image showing apparent layering at low resolution. B) Breccia pods crosscut topography and apparent layering continues into the smooth, unbrecciated rock in the lower left, but with a sinuous geometry (dashed line indicated by arrow). Light blue lines represent 2 m elevation contours. C & D) Breccia pods define apparent layering, but are not laterally continuous either on surfaces with low relief (C) or sloping surfaces (D)



Please see Sumner, 2010, Workshop #4 Presentation for Documentation of Brecciation of the bedrock in the Mawrth Landing Ellipse

Physical Outcrop Characteristics of the Mawrth Candidate Landing Site & the Potential Role of Impacts in Shaping Stratigraphy http://marsoweb.nas.nasa.gov/landingsites/msl/workshops/4th_workshop/program.html

Conclusion:



A mission at the currently defined Mawrth ellipse would be predominantly an investigation of the effects of the Oyama impact on pre-existing bedrock.

This is a very unfortunate result, as I set out in search of evidence that would refine interpretations of a sedimentary environment. It would have been nice to find evidence of an old sedimentary environments with diverse hydrous minerals that are easily accessible to MSL at Mawrth. However, I do not see evidence for sedimentary deposits that preserve evidence of habitatibility even though I have evaluated HiRISE or CTX images in detail at each location near the landing ellipse where such evidence has been proposed in the literature or at a landing site workshop.